Evaluation of the Utility of the Global Sea Level Observation by **TOPEX/POSEIDON** for Estimating the Ocean Circulation

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The variability of the sea level is an integrated response to both thermodynamic and dynamic changes in the ocean. Seasonal heat exchange between the ocean and the atmosphere accounts for most of the large-scale sea level variability at the mid and high latitudes. At the tropical latitudes, the large-scale sea level responds primarily to the changing winds. The ubiquitous mesoscale variability is largely the result of the dynamic instability of ocean currents as well as the forcing by the wind. Observation of the sea level is thus a rich source of information about the ocean, providing a powerful constraint for numerical models for the purpose of simulating the ocean circulation and its effects on climate change.

Satellite altimetry is a technique utilizing a precision radar altimeter system for measuring the sea level of the world's oceans. The measurement geometry of satellite altimetry is illustrated in Figure 1. The height of the sea surface relative to the Earth's center of mass (defined as the sea level) is obtained by subtracting the altimeter range measurement from the geocentric altitude of the spacecraft (the radial orbit height). But the accuracies required to be useful approach 1 cm, and achieving them requires solutions to a host of technical problems. The launch of the joint United States/France TOPEX/POSEIDON Mission on August 10, 1992 marked the culmination of the altimetry technology developed over the past two decades (Fu et al., 1994). Shown in Figure 2 is a comparison of the performance of TOPEX/POSEIDON with three other recent satellite altimeters. Only TOPEX/POSEIDON has sufficient accuracy for detecting the large-scale oceanic signals.

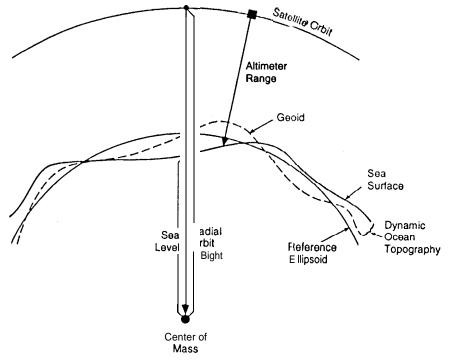
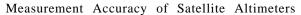


Fig. 1 The geometry of the technique of satellite altimetry



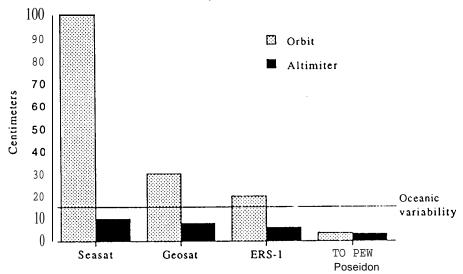


Fig. 2 The evolution of the measurement accuracy of various satellite altimeters. The horizontal line denotes a representative sea level change (15 cm) caused by the variations of large-scale ocean currents.

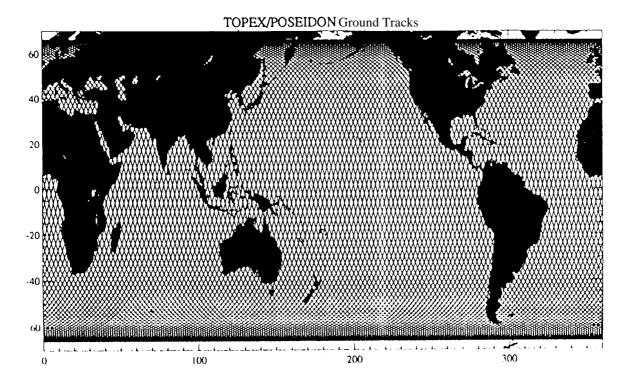
TOPEX/POSEIDON is measuring the global sea level along the ground tracks shown in Figure 3. Due to the desire to measure the ocean tides and **remove** them from the data for circulation studies, the inclination of the orbit plane with **respect** to the equatorial plane is 66 degrees. Nevertheless, the ground tracks provide 95 % coverage of the ice-free ocean (altimetry does not work over ice). Highlights of the results from the mission will be presented.

Evaluation of the utility of this data set in constraining ocean circulation models is conducted using the approach of data assimilation. **Specifically,** we explore the extent to which the sea level observation provides constraint for estimating the velocity and temperature fields at depths.

The effectiveness of assimilation of altimetry data into numerical models depends on the ways by which the information propagates to the deep levels. For quasi-geostrophic models, the stream functions of the various layers are tightly coupled and the sea level information can be readily assimilated into the deep levels. For primitive-equation model, the transfer of information from the sea level to other variables at depths is not straightforward. Techniques involving the use of empirically estimated correlation of the sea level with subsurface fields have been applied to the problem. But such an approach lacks dynamical consistency of the sea level with other variables in the information transfer process. Furthermore, there are no formal mechanisms for estimating the errors in the estimation of the subsurface fields. To overcome these deficiencies, we use the Kalman filter technique that is formally an optimal estimation approach to the problem.

The application of the Kalman filter technique carries an enormous computational burden because the forecast error covariance matrix needs updating at each time step, a prohibitive aspect for applications to the ocean general circulation models. We use the technique developed by Fukumori et al. (1993) and Fukumori and Malanotte-Rizzoli (1995) for achieving approximate Kalman falters (also see Fukumori, this symposium), which are then used with an ocean circulation model in assimilating the TOPEX/POSEIDON data. The objective is to evaluate the propagation of the altimetry errors into the estimation of the

subsurface velocity and **temperature** fields. An error **covariance** model for the altimetry errors will be **developed** and applied to the estimation. Results will be **compared** to in-situ observations.



Fig, 3 The ground tracks along which the **TOPEX/POSEIDON** satellite is making sea level observations at a rate of one **record** every second of flight time (or every 6.2 km along the track). The satellite repeats these tracks every 9.96 days and produces a "snap shot" of the **sea** level of the world's oceans.

<u>Acknowledgements</u>

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